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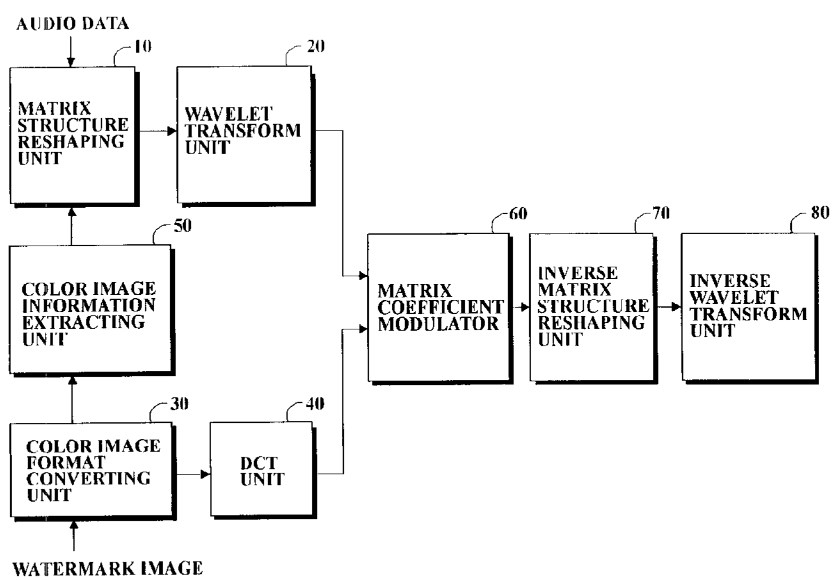
(54) Title: DIGITAL WATERMARKING METHOD AND APPARATUS USING A COLOR IMAGE AS A WATERMARK



(57) Abstract: A color image of relatively large size is inserted in audio signal data as a watermark. And yet the watermark embedded audio signal data can be played back with sound quality very close to that of original audio signal data. The original audio signal data are reshaped into a matrix form to correspond to that of a color image file before wavelet transformed while the color image file undergoes a format conversion before discrete cosine transformed. The coefficients of the transformed audio signal data and the reformatted color image are combined before inverse-matrix-reshaped and subsequently inverse-wavelet-transformed to finally generate an audio signal wherein a color-image watermark has been inserted.

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DIGITAL WATERMARKING METHOD AND APPARATUS USING A COLOR IMAGE AS A WATERMARK

TECHNICAL FIELD

The present invention relates to digital watermarking of data, including audio, video and multimedia data. Specifically, the invention relates to embedding a watermark signal of relatively large data size, such as a color image, into digital audio data.

BACKGROUND ART

The proliferation of digitized media such as image, video and multimedia is creating a need for security systems that facilitate the identification of the source of the material. Particularly, the internet is increasingly used for transmitting recorded music in a digitized format. Content providers, i.e., owners of such recorded music in digital form, have a need to embed into multimedia data a predetermined mark, which can subsequently be detected by software and/or hardware devices for purposes of authenticating copyright ownership, control and management of the multimedia data. A digital watermarking method has been developed as a technique for embedding identifiable data into multimedia data.

Conventionally, watermark signals used for watermarking audio signal have been relatively simple signals such as a sequence of code symbols because, unlike inserting a watermark into image or video, inserting a large watermark signal would affect the perceptibility of an original audio. Moreover, the prior art watermarking techniques are susceptible to unauthorized removal of

watermarks, thereby making hard to trace the origin of a copyright protected material.

DISCLOSURE OF THE INVENTION

It is, therefore, a primary object of the present invention to imbed relatively large color image data in audio signal data without losing the quality of the audio signal when it is played back. The watermarking embedding method thus provides very high correlation between an original audio signal and its watermarked version. This object is achieved in part by reshaping audio data structure in a matrix to correspond to an image file to be inserted and performing frequency domain transformations.

In accordance with one aspect of the present invention, there is provided a method for inserting color image watermark data into audio data which comprises steps of: converting said color image watermark data from a first mode to a second mode; reshaping said audio data into a matrix to correspond to that of said color image watermark data in converted in said second mode; wavelet transforming said reshaped audio data in a frequency domain to generate first spectral coefficients; discrete cosine transforming said color image data of said second mode in a frequency domain to generate second spectral coefficients; combining said first and second spectral coefficients; and transforming said combined coefficients to generate color image embedded audio data.

In accordance with another aspect of the present invention, there is provided a digital watermarking apparatus for inserting color image watermark data into audio data which comprises: a means for converting said color image watermark data from a first mode to a second mode; a means for reshaping said audio data into a matrix to

correspond to that of said color image watermark data in converted in said second mode; a means for wavelet transforming said reshaped audio data in a frequency domain to generate first coefficients; a means for discrete cosine transforming said color image data of said second mode in a frequency domain to generate second coefficients; a means for combining said first and second coefficients; and a means for transforming said combined coefficients to generate color image embedded audio data.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram for inserting a watermark signal into audio signal data according to the present invention;

Fig. 2 illustrates a Fast Wavelet Transform (FWT);

Fig. 3 illustrates an inverse Fast Wavelet Transform (IFWT);

Fig. 4 shows a color image watermark used in an experiment;

Fig. 5 shows the spectrum of an original digital audio data;

Fig. 6 shows the spectrum of a watermark embedded digital audio data according to the present invention;

Fig. 7 shows the color image watermark after it is extracted from the watermark embedded digital audio data; and

Fig. 8 illustrates a distribution mechanism for watermarked audio data according to the present invention.

MODES OF CARRYING OUT THE INVENTION

Referring to Fig. 1, the present invention will be described in detail hereinafter. A matrix structure reshaping unit 10 is configured to reshape original audio data in a matrix format identical to that of a color image as a watermark to be inserted later on. The original audio data in a stream is broken into sections such that the size of each section becomes identical to that of an image file. The image file can be inserted into every section of the audio data although intermittent insertion is preferred. Meanwhile, a color image format converter 30 converts an original color watermark image file of a format such as BMP(bitmap) or JPEG(joint photographic coding expert group) format to a YIQ format, where Y represents luminescence and I and Q represent in-phase and quadrature components, respectively. The conversion makes possible a fast processing of a large color image in a later stage. In the present invention, only the Y component will be used. After this conversion, the scale, size, color information and bit structure of the converted image file are extracted by a color image information extracting unit 50 and provided to the matrix structure reshaping unit 10, which uses this information to reshape the original audio data as mentioned above.

The reshaped audio data and the YIQ converted image data are transformed in the frequency domain by a wavelet transform unit 20 and a discrete cosine transform unit 40, respectively. A Fourier transform has been used to convert a watermark in the frequency domain to conceal the content of the watermark. In case that an impulse type watermark is transformed, its spectral coefficients spread all across the spectrum, making it hard to remove it once it is inserted into a target data. However, coefficients of the Fourier transform are complex numbers so that they can not be easily

added to the target data. Therefore, a discrete cosine transformation(DCT) is preferred in the DCT unit 40 because, though similar to of the Fourier transform, particularly a fast Fourier transform, it results only in real coefficients in the transformed domain. Conventionally, a DCT has been used to encode signals. For example, it is used for compression of data in JPEG standard. Basically, it is defined as follows:

$$t(k) = c(k)\sum_{n=0}^{N-1} s(n)\cos\frac{\pi(2n+1)k}{2N} \qquad \text{Eq. (1)}$$

where *s* is the original value of *N* and *t* is the converted value of *N*. The coefficients *c* are further defined as follows:

$$c(0) = \sqrt{1/N}, c(k) = \sqrt{2/N} \quad \text{for} \quad 1 \le k \le N-1 \qquad \text{Eq. (2)}$$

Using the two definitions above, a two-dimensional DCT is given by the following:

$$t(i,j) = c(i,j)\sum_{n=0}^{N-1}\sum_{m=0}^{N-1} s(m,n)\cos\frac{\pi(2m+1)i}{2N}\cos\frac{\pi(2n+1)i}{2N} \qquad \text{Eq. (3)}$$

where *N*, *s*, *t* represent the same parameters as those in one-dimensional DCT and *c(i,j)* is defined as follows:

$$c(0,j) = 1/n, c(i,0) = 1/N, c(i,j) = 2/N \quad \text{for} \quad i \neq 0, j \neq 0 \qquad \text{Eq. (4)}$$

There is an inverse DCT, which is defined in one-dimension and two-dimension as follows, respectively.

$$s(n) = \sum_{k=0}^{N-1} c(k)t(k)\cos\frac{\pi(2n+1)k}{2N} \qquad \text{Eq. (5)}$$

$$s(m,n)=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}c(i,j)t(i,j)\cos\frac{\pi(2m+1)i}{2N}\cos\frac{\pi(2n+1)i}{2N} \qquad \text{Eq. (6)}$$

To transform the reshaped audio data, a wavelet transformation is used in the wavelet transform unit 20. The Wavelet transform uses wavelets as its basic functions just as the Fourier transform uses sine and cosine functions as its basic functions. The Wavelet transform falls in two categories. One of them is continuous wavelet transform, which is defined similarly to the Fourier transform as follows:

$$W(s,\tau)=\int_{-\infty}^{\infty}f(t)\varphi(s,t)dt \qquad \text{Eq. (7)}$$

where s is a scaling factor and τ is a transform coefficient.

A compressed wavelet has a low scale and expresses high frequency components while enlarged wavelet expresses low frequency components at a high scale. Thus the scale and the frequency are inversely proportional. The number of the coefficients generated by continuous wavelet transform is infinity because they are a function of scaling and position displacement. Thus a discrete wavelet transform depending on a subset of scaling and position displacement is used. More effective algorithm is possible by determining scaling and position displacement depending on dyadic. Nevertheless, still it requires a large volume of computations. In order to make up this drawback, a fast wavelet transform is suggested. This transform employs a conventional two-channel subband coding and a pyramid algorithm, and can be applied relatively simply with a so-called perfectly reconstructive quadrature mirror filter, an interconnection among filter banks for inverse transform. Fig. 2 and Fig. 3 represent a known fast wavelet transform and a known inverse fast wavelet transform, respectively.

After the transformations as described above, the

thus-generated coefficients of the transformed audio data and image are each modulated at a matrix coefficient modulator 60, for instance, by multiplying a scaling factor, in order to minimize the distortion of the original audio as the result of the watermark insertion. After the adjustment, the two sets of coefficients are added together. Next, the combined coefficients are rearranged at the inverse matrix structure reshaping unit 70 so that their structure is identical to that of the original audio data. Finally, the rearranged coefficients are inverse wavelet transformed at a inverse wavelet transform unit 80 to generate a color image embedded audio signal data.

Fig. 4 represents the spectrum of the original audio signal and Fig. 5 shows a color image that is to be inserted in the audio signal in an experiment. Fig.6 represents the spectrum of the audio signal with the color image embedded according to the present invention. As can be easily seen from the figures, the two spectrums are almost identical to each other with the implication that the original audio signal was not negatively affected. The correlation between the two signals was obtained with the following formula widely used in the art:

$$C = \frac{W(i,j)}{\sqrt{W(i,i) * W(j,j)}} \qquad \text{Eq.(8)}$$

Experiments showed 98.5% correlation, which is well above the minimum correlation of 95% because the present invention can reduce distortion of the original audio signal even when a relatively large image file is inserted. Furthermore, the extracted watermark has over 75% correlation with the original watermark image. Fig. 7 shows the watermark of Fig. 5 after it was extracted from the watermark embedded signal. The extracted watermark is easily identifiable as that of the original watermark.

Fig. 8 illustrates one of environments in which the present invention is taken advantage of. The watermarked audio data, generated from a watermarking unit 100, as described above referring to Fig. 1, may be stored in a database 200 for on-line distribution/downloading to remote computers 600 by way of an on-demand server 400. For this, such an on-demand server is preferably connected a communication network formed by a high-speed communication network, for example, such as a B-ISDN or an ATM-LAN. To be concrete, the communication network is an open network represented by the internet 500, or a network using a private circuit of personal computer communication or the like. Thus access to the server, providing watermarked audio data stored in the database, by remote computers or terminals is possible. The watermark itself can be stored in another database 300 for downloading to authorized persons in order to verify the extracted watermark is genuine.

The present invention may be further used in the field of digital image verification and protection, including verifying and protecting the integrity of digital images stored in memory for authentication and security purposes, that has recently gained importance and wide recognition.

It involves determining whether a digital audio/image had been modified. In this technique, an information/watermark is "stamped" in an original audio/multi-media data. This stamping technique is unlikely to cause audio/visual artifacts in the original data.

While there has been described and illustrated methods and systems for inserting a color image watermark data by discrete cosine transforming the watermark signal and wavelet transforming an original audio data, it will be apparent to those skilled in the art that variations and modifications are possible without deviating from the broad principles and teachings of the present invention which

should be limited solely by the scope of the claims appended hereto.

WHAT IS CLAIMED IS:

1. A method for inserting color image watermark data into audio data, comprising steps of:

(a) converting said color image watermark data from a first mode to a second mode;

(b) reshaping said audio data into a matrix to correspond to that of said color image watermark data in converted in said second mode;

(c) wavelet transforming said reshaped audio data in a frequency domain to generate first spectral coefficients;

(d) discrete cosine transforming said color image data of said second mode in a frequency domain to generate second spectral coefficients;

(e) combining said first and second spectral coefficients; and

(f) transforming said combined coefficients to generate color image embedded audio data.

2. The method of claim 1, further comprising steps of:

(g) obtaining information about said color image watermark data; and

(h) using said information in said step (b).

3. The method of claim 2, wherein said information includes one or more of the image size, the number of colors in each pixel and bit array structure.

4. The method of claim 1, wherein said step (f) includes steps of:

(f1) inverse reshaping said combined coefficients into

an original data structure of said audio data; and

(f2) inverse wavelet transforming said reshaped combined coefficients to generate a watermark embedded audio data.

5. The method of claim 1, wherein said first mode is RGB mode and said second mode is YIQ mode, where R, G and B represent red, green and blue components of a pixel, respectively, and Y, I and Q represent luminescence, in-phase and quadrature components of a pixel, respectively.

6. A digital watermarking apparatus for inserting color image watermark data into audio data, comprising:

a means for converting said color image watermark data from a first mode to a second mode;

a means for reshaping said audio data into a matrix to correspond to that of said color image watermark data in converted in said second mode;

a means for wavelet transforming said reshaped audio data in a frequency domain to generate first coefficients;

a means for discrete cosine transforming said color image data of said second mode in a frequency domain to generate second coefficients;

a means for combining said first and second coefficients; and

a means for transforming said combined coefficients to generate color image embedded audio data.

7. The digital watermarking apparatus of claim 6, further comprising:

a means for obtaining information about said color image watermark data; and

a means for using said information in said means for reshaping.

8. The digital watermarking apparatus of claim 7, wherein said information includes one or more of the image size, the number of colors in each pixel and bit array structure.

9. The digital watermarking apparatus of claim 6, wherein said transforming means further includes:

a means for inverse reshaping said combined coefficients into an original data structure of said audio data; and

a means for inverse wavelet transforming said reshaped combined coefficients to generate watermark embedded audio data.

10. The digital watermarking apparatus of claim 6, wherein said first mode is RGB mode and said second mode is YIQ mode, where R, G and B represent red, green and blue components of a pixel, respectively, and Y, I and Q represent luminescence, in-phase and quadrature components of a pixel, respectively.

11. The digital watermarking apparatus of claim 6, further comprising a storage means for storing said watermark embedded audio data and said color image watermark.

12. The digital watermarking apparatus of claim 11, further comprising a server connected to a communication network for communicating said watermark embedded audio data stored in said storage means to remote terminals coupled to

said communication network.

FIG. 1

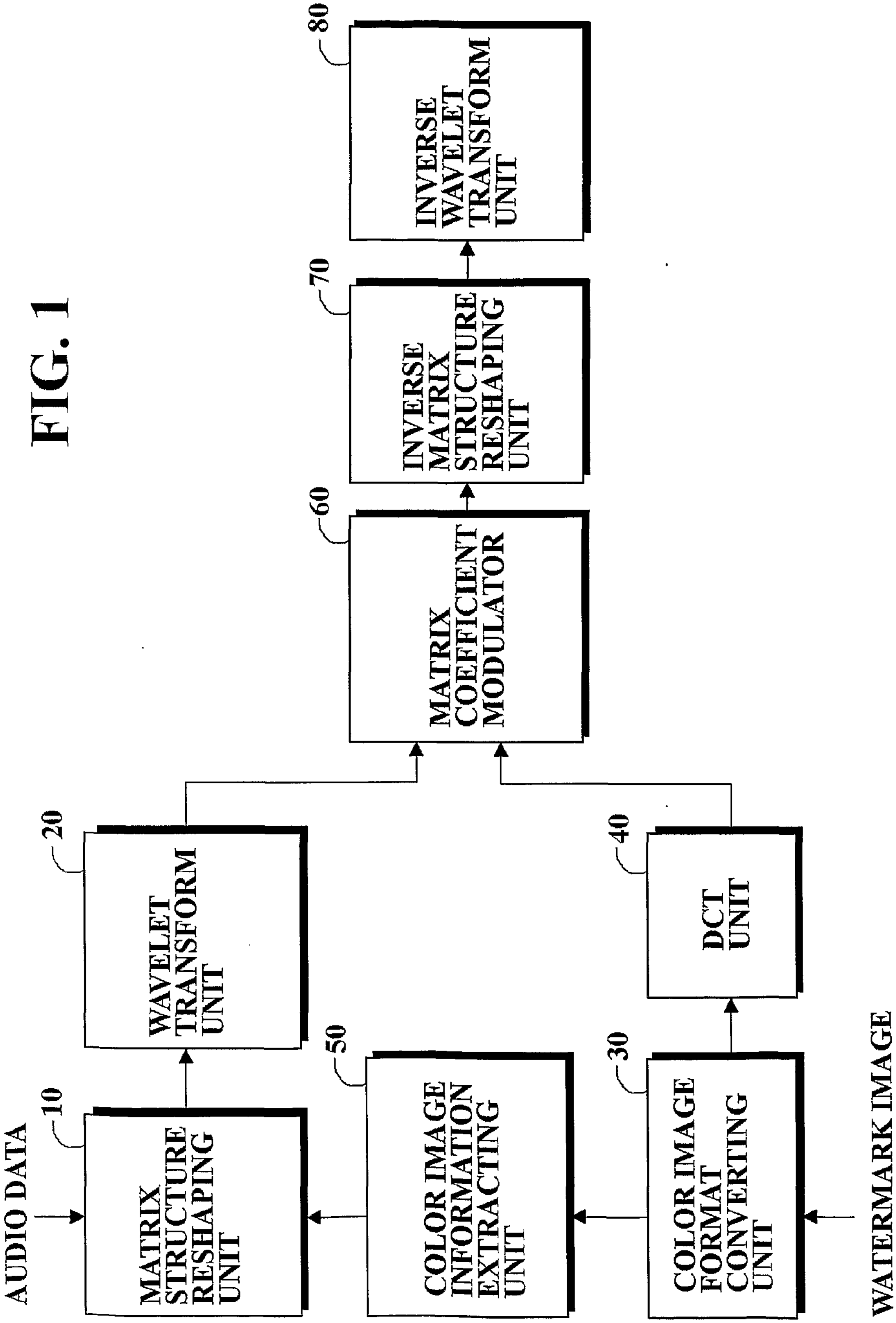

AUDIO DATA
10
MATRIX STRUCTURE RESHAPING UNIT
20
WAVELET TRANSFORM UNIT
50
COLOR IMAGE INFORMATION EXTRACTING UNIT
30
COLOR IMAGE FORMAT CONVERTING UNIT
WATERMARK IMAGE
40
DCT UNIT
60
MATRIX COEFFICIENT MODULATOR
70
INVERSE MATRIX STRUCTURE RESHAPING UNIT
80
INVERSE WAVELET TRANSFORM UNIT

FIG. 2

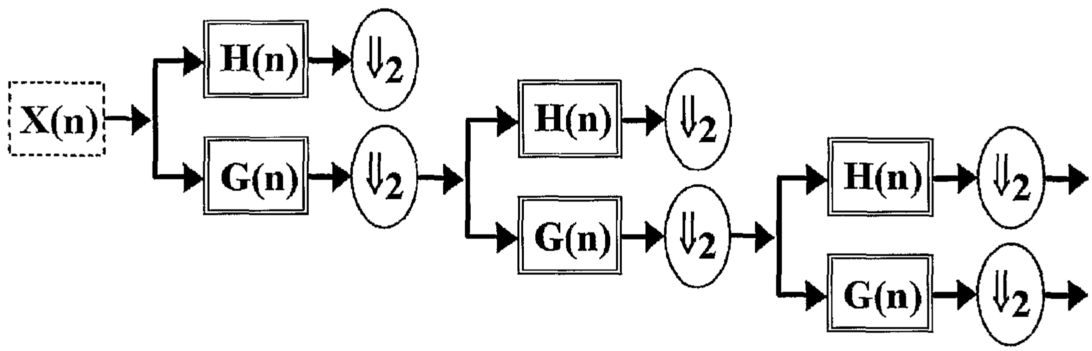


FIG. 3

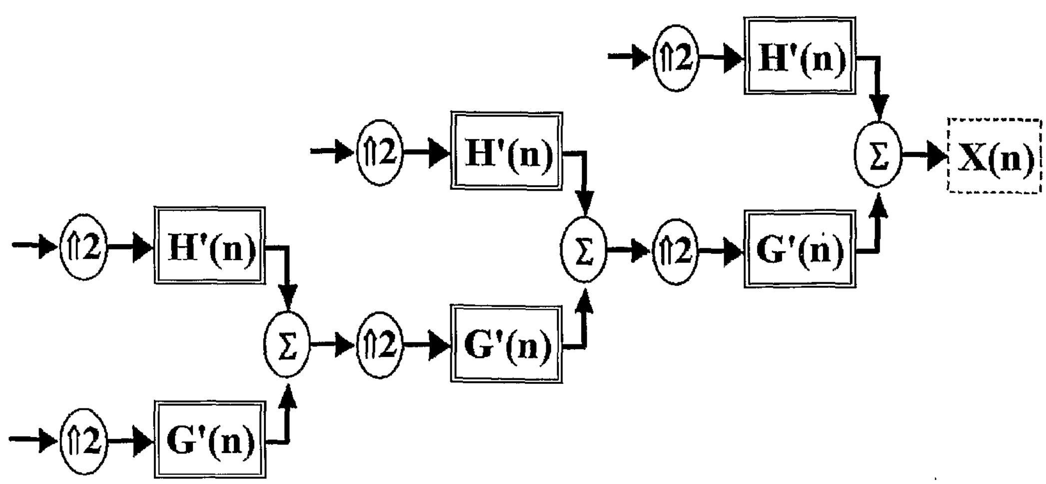


FIG. 4

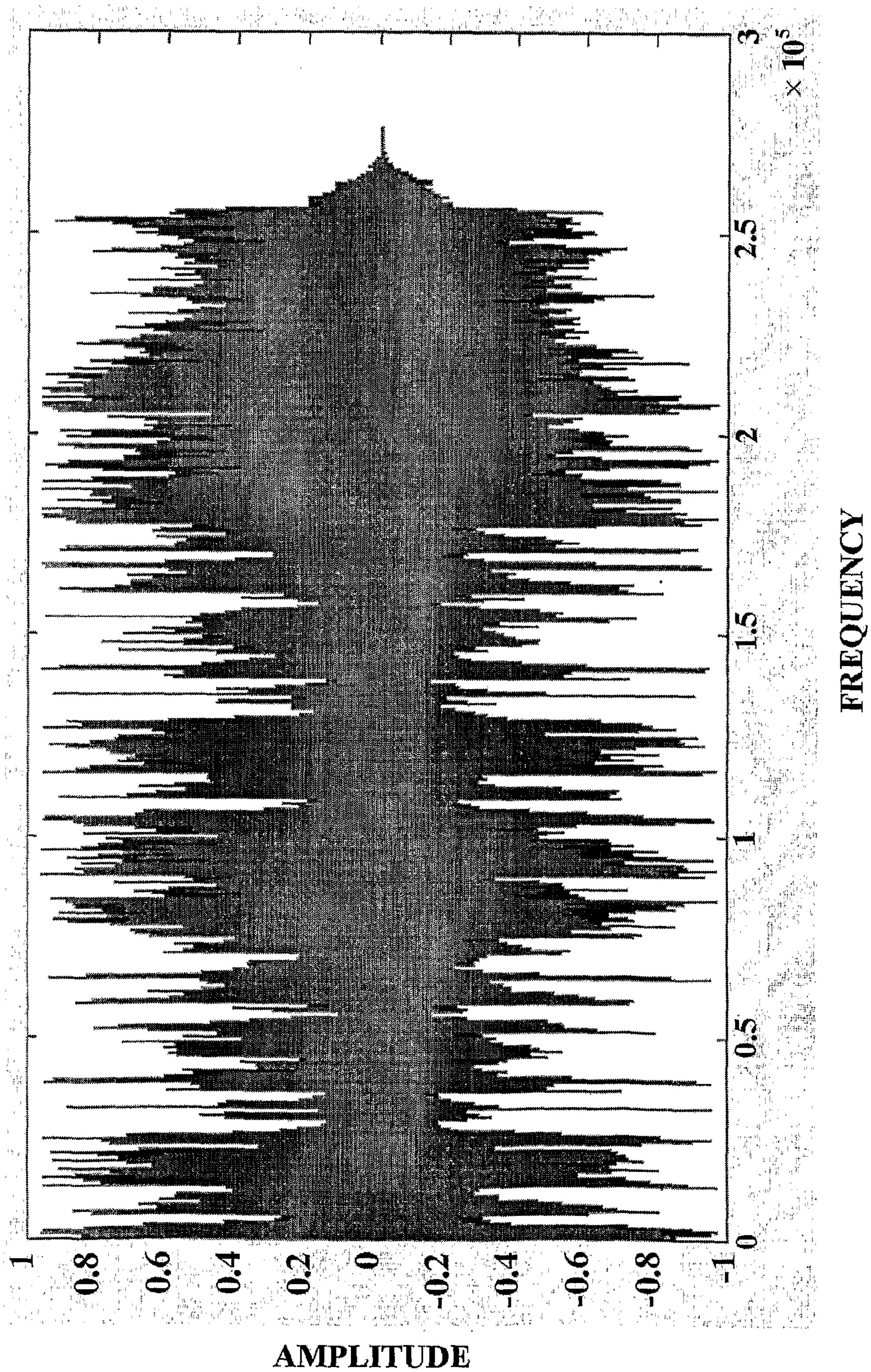

FREQUENCY
AMPLITUDE
0
0.5
1
1.5
2
2.5
3
× 10^5
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

FIG. 5

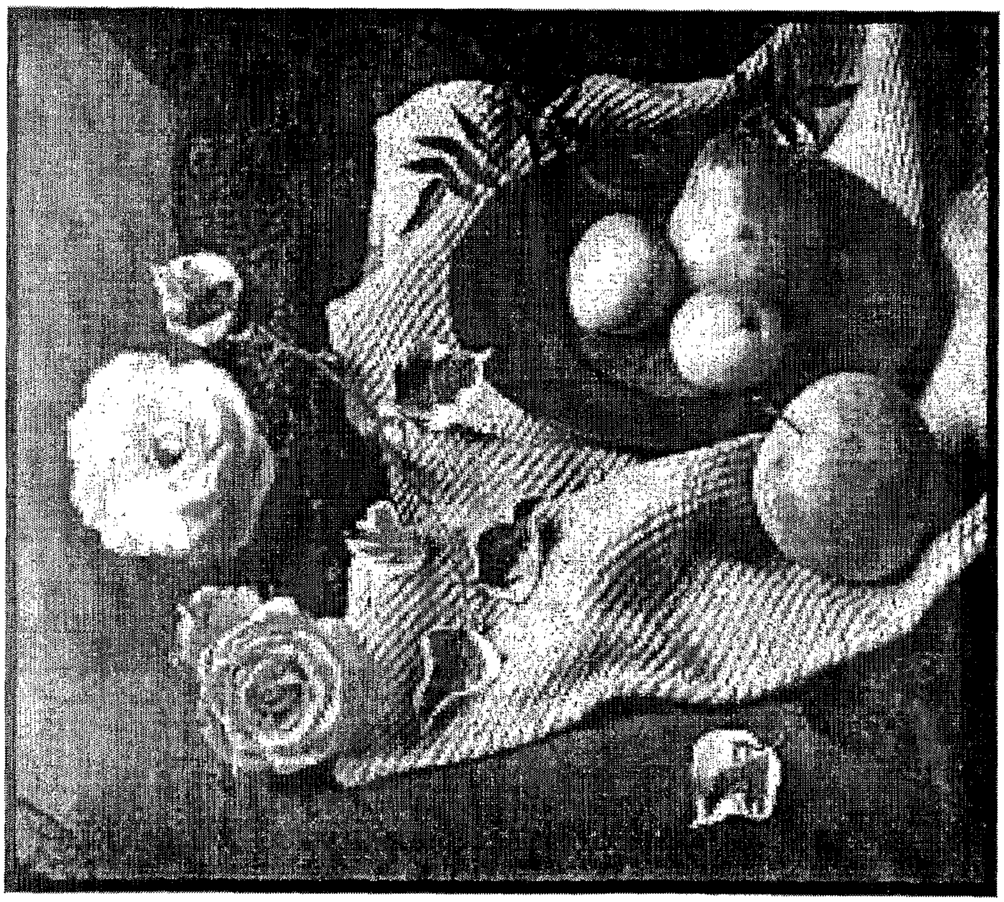


FIG. 6

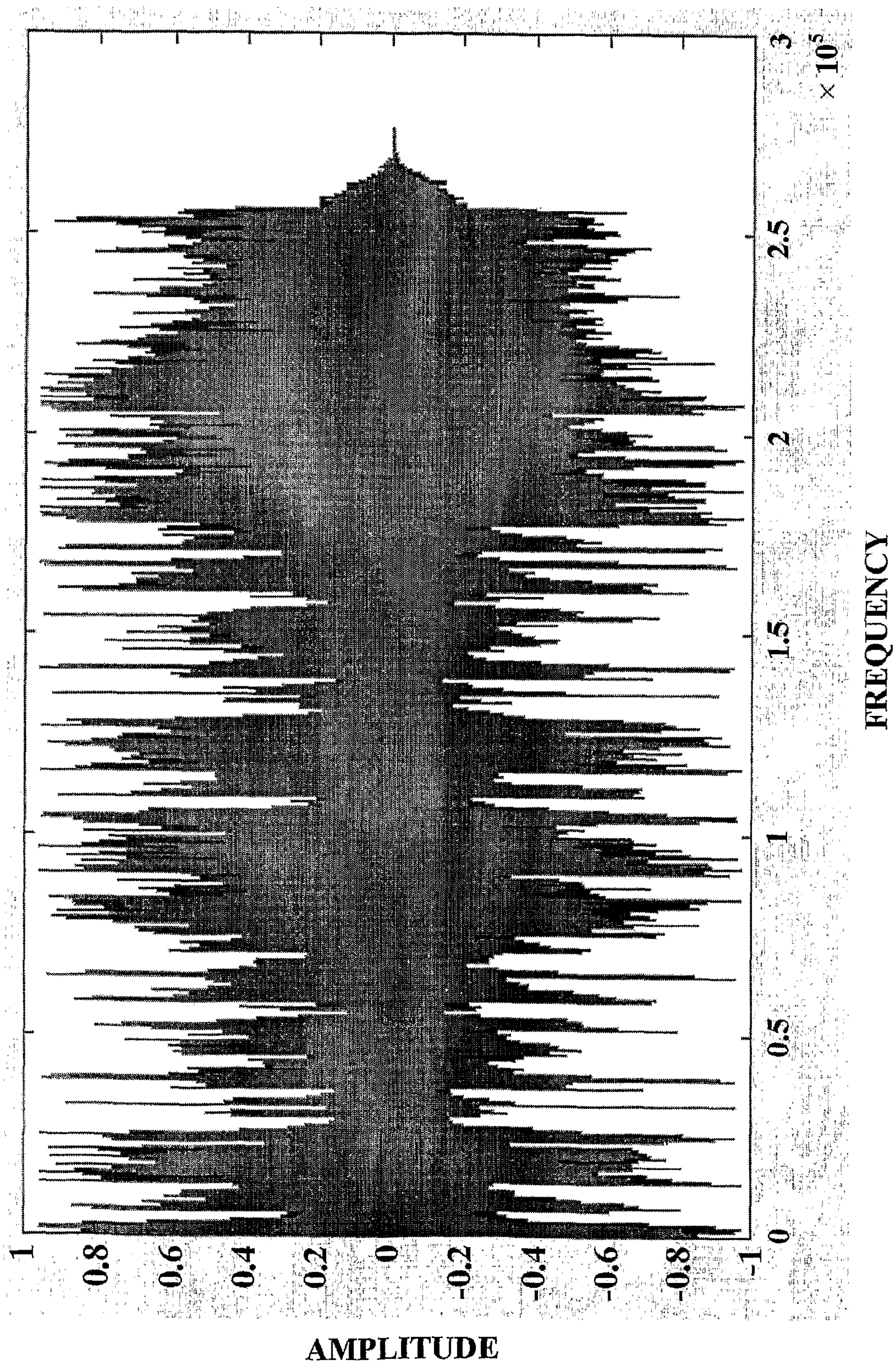


FIG. 7

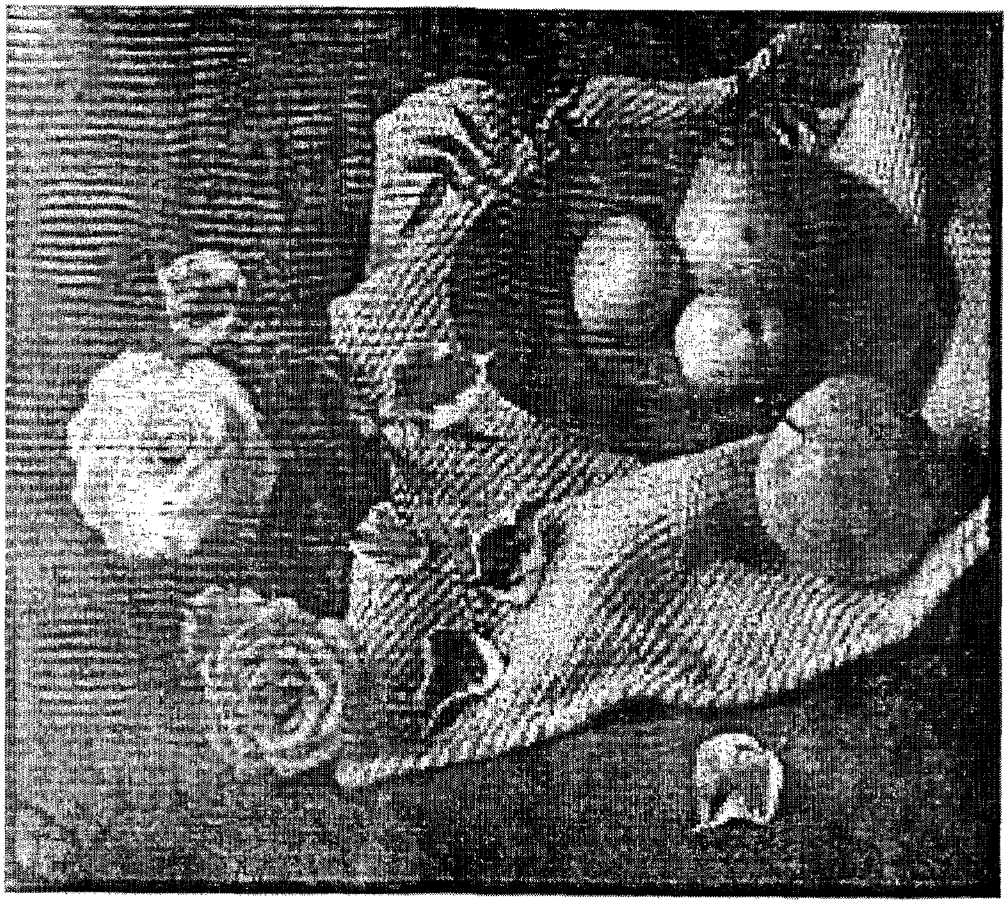
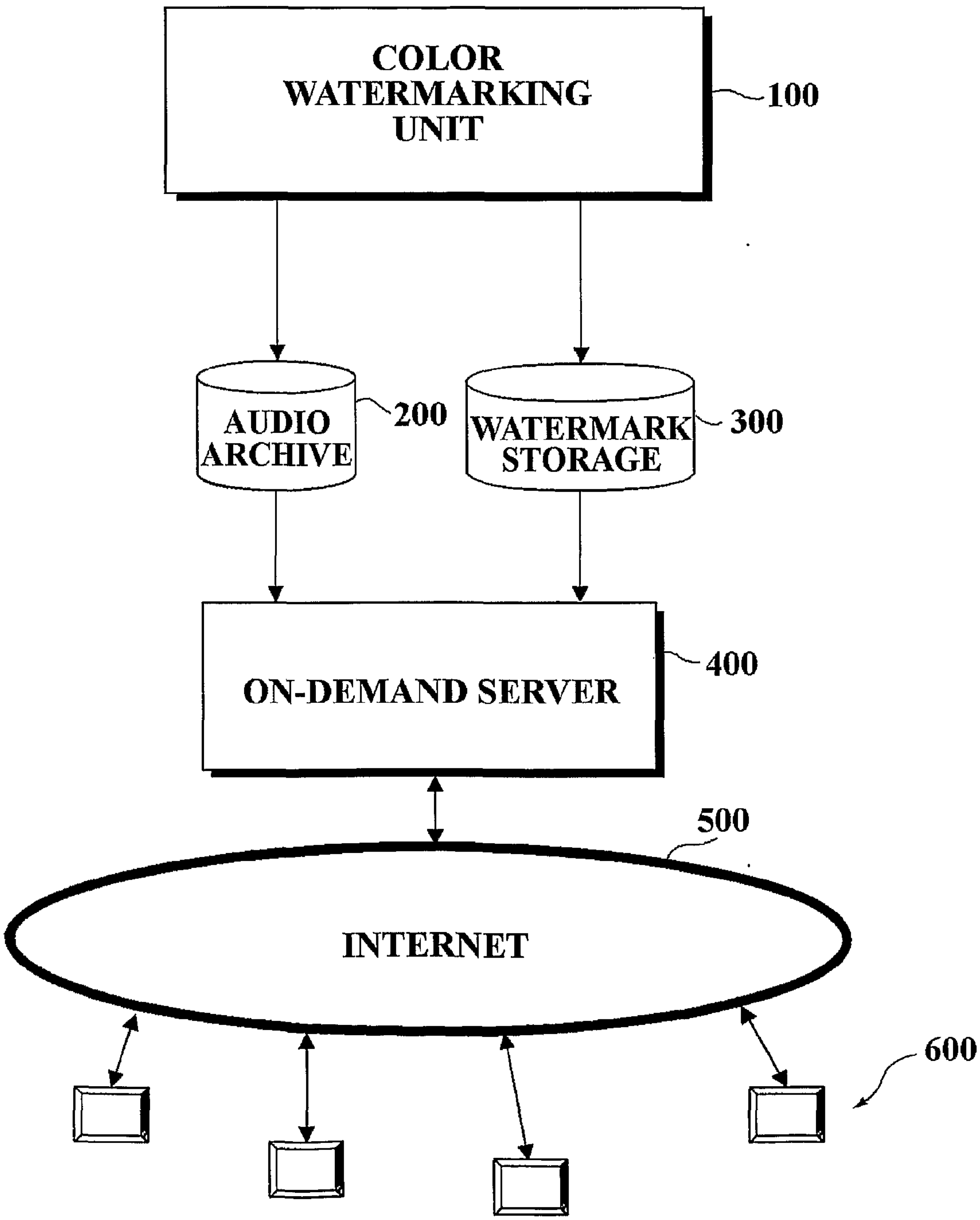


FIG. 8


COLOR WATERMARKING UNIT
100
AUDIO ARCHIVE
200
WATERMARK STORAGE
300
ON-DEMAND SERVER
400
500
INTERNET
600

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 00/00645

CLASSIFICATION OF SUBJECT MATTER

IPC[7]: G09C 5/00; H04L 9/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[7]: G09C, H04L, G06T, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

IEEE Xplore, WPI, EPODOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 99/63443 A1 (DATAMARK TECHNOLOGIES PTE LTD) 9 December 1999 (09.12.99) figs. 1,2,5-7; abstract; claims 1-15,19-22,25,32,62,64; page 9, lines 14-33; page 10, line 25 - page 11, line 14; page 12, lines 9-30.	1-4,6-9,11,12 5,10
A	EP 0766468 A2 (NIPPON ELECTRIC CO) 2 April 1997 (02.04.97) figs., abstract.	1-12
A	US 5930369 A (COX et al.) 27 July 1999 (27.07.99) figs., abstract.	1-12

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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„&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR 00/00645

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
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				JP	A2	9191394	22-07-1997
				US	A	5930369	27-07-1999
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				AU	B2	701639	04-02-1999
				CA	AA	2184949	29-03-1997
				EP	A2	766468	02-04-1997
				EP	A3	766468	07-07-1999
				JP	A2	9191394	22-07-1997
				US	BA	6208735	27-03-2001
WO	A1	9963443	09-12-1999	AU	A1	76833/98	20-12-1999